SERVM Production Cost Modeling Results: 38 MMT Core Portfolio with 2020 IEPR-High EV IRP R.20-05-003

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California Public Utilities Commission

Purpose

- Present SERVM production cost modeling (PCM) to support the Integrated Resource Plan (IRP) Preferred System Plan (PSP) Proposed Decision
  - 38 MMT Core Portfolio updated to pair with the California Energy Commission's 2020 Integrated Energy Policy Report (IEPR) Update electric demand forecast – managed mid demand paired with high electric vehicle demand
- This portfolio is also proposed for transmittal to the CAISO for use in its 2022-23 Transmission Planning Process (TPP) base case

Contents

- Background and summary of results
- Descriptions of inputs, modeling conventions, recent updates
- Reliability and PCM analysis results
- Criteria pollutant analysis results

Background

- An August 17th, 2021 Commission ruling seeking comments on the proposed PSP described staff analysis using the RESOLVE and SERVM models of several scenarios/sensitivities being considered for the PSP
- Attachment B to the ruling was a staff presentation describing SERVM reliability and PCM results. Staff also presented these results at a public workshop on September 1st, 2021. The presentation was posted here, and included:
  - Description of the SERVM PCM framework used by staff
  - Probabilistic reliability model definitions
  - History of model input updates
  - Definition of the 38 MMT Core Portfolio
  - Description of key modeling conventions

Summary of results

For the 38 MMT Core Portfolio updated to pair with the 2020 IEPR managed mid demand forecast and high electric vehicle demand:

- LOLE is below the 0.1target in all studied years – the portfolio is reliable
- Installed capacity is generally aligned with the same modeled case in RESOLVE
- Annual generation results are reasonable and differences from RESOLVE can be explained by certain differences between the two models
- Annual emissions are sufficiently close to the 38 MMT statewide target in 2030, and to what is modeled in RESOLVE in 2026 and 2032
- Total criteria pollutants from California electric generators decrease about 7% between 2026 and 2032 due to a shift from fossil generation to geothermal and other renewable generation
- Findings on electric sector criteria pollutants are consistent with those in the previous staff analysis (2/21/2020)

Reliability and PCM analysis of the updated 38 MMT Core Portfolio proposed for the PSP

Study definition

- Study years: 2026, 2030, 2032
- Electric demand input: 2020 IEPR Update demand forecast – managed mid demand paired with high electric vehicle demand
- 38 MMT Core Portfolio described in the August 17th ruling
  - Existing Baseline
  - Aggregated 38 MMT LSE plans
  - Mid Term Reliability procurement
- RESOLVE-selected incremental resources from the August 17th ruling 38 MMT Core Portfolio were replaced by a new set of RESOLVE-selected incremental resources coming from a rerun of RESOLVE updated to use the 2020 IEPR (managed mid demand/high electric vehicle), plus other minor RESOLVE updates
  - Corrected representation of OTC extensions in 2022 and 2023
  - Updated planned capacity of utility-scale battery storage from 2022 through 2045
  - Updated fixed O&M costs for existing and new candidate resources

IEPR demand forecast input detail

- Mid demand, Mid-mid AAEE
- Electric vehicle demand from the IEPR High case
- Extrapolation to 2032 (since most 2020 IEPR demand components end at 2030) following same methods used in RESOLVE
  - Linear extrapolation using values from last five years of forecast
  - Exception: BTM storage impact held at 2030 level through 2032
  - Exception: BTM CHP generation assumed to linearly decline to zero from 2030 to 2040

Comparison of annual peak and energy between 2019 and 2020 IEPR demand forecast

	Total CAISO Noncoincident Peak (MW)			
	2022	2026	2030	2032
2019 IEPR	48,077	49,107	50,557	
2020 IEPR	48,605	50,149	51,531	52,330

	Total CAISO energy to serve load (GWh)			
	2022	2026	2030	2032
2019 IEPR	224,195	229,868	235,261	
2020 IEPR	218,010	228,160	232,697	235,249

Key modeling conventions

- 4,000 MW import restriction – imposed from HE17-HE22 (4pm-10pm), June-September
- Modeled CAISO hourly reserve requirements, including spin, non-spin, regulation, load following, quickstart reserves, frequency response
  - Loss-of-load event defined when 3% (of hourly demand) spinning reserves or 3% regulation up reserves are not met
- Certain assumptions reflect historical data and do not yet account for climate change
  - Hydro assumptions are based on 1998-2017 hydro patterns, which means California's recent low hydro years after 2017 are not yet considered. Hydro conditions (wet, dry) and timing (seasonal shifts) may vary more across the West in future years due to climate change.
  - Electric demand and wind and solar generation are based on 1998-2017 weather, so more extreme temperatures or changes in wind and solar patterns in recent years and predicted for the future are not yet considered
  - Likewise, other planning assumptions may not fully represent a climate change future
  - In 2022, staff expects to consider model changes to better account for climate change effects

Modeling changes since September 2021 (1 of 2)

- Added a 5% average outage rate to all storage categories (batteries, both paired and stand-alone, BTM batteries, and pumped storage)
- Added a 90% discharge cap to batteries, both paired and stand-alone (but not pumped storage since it is a different technology)
  - Cap only applies when hourly generation is sufficient to meet demand and required reserves; cap is ignored if loss-of-load is imminent
  - Meant to reflect real world observations in the CAISO market that storage usually does not fully discharge because frequent complete discharging incurs higher battery maintenance costs
- Storage outage rate and discharge cap are modeled only in SERVM, not in RESOLVE – staff expects to align in the models in 2022
- Increased the storage price (from $40 to $900) that controls when storage dispatch overrides its economic dispatch schedule. In all previous SERVM analysis, this price was set too low and storage was frequently used for energy arbitrage during lower demand hours rather than staying optimized to discharge during peak demand hours.

Modeling changes since September 2021 (2 of 2)

- Constrained about 2,400 MW of paired battery storage to charge from its paired generator (solar)
- Set each of the four modeled regions within the CAISO region to be required to maintain their own operating reserves and not share across the CAISO region
- Retired oldest 360 MW of combined heat and power (CHP) units in 2032, consistent with RESOLVE's assumption of CHP generation declining linearly from 2030-2040
- Updated SERVM software version 8.11_CPUC

Summary of input fleets, RESOLVE vs. SERVM

RESOLVE scenario name: 38MMT_20211005_PSP_LSEplan_2020IEPR_2020IEPRHighEV
SERVM study name: 38MMT_PSP_2020HEV_Study_9
Installed Capacity (MW) comparison by category for 2026, 2030, and 2032

	2026		2030		2032	
Unit Category	RESOLVE	SERVM	RESOLVE	SERVM	RESOLVE	SERVM
Battery Storage	13,296	13,112	14,374	14,235	15,550	15,294
Biomass	917	899	942	928	942	928
BTM Battery Storage	1,687	1,687	2,592	2,592	2,592	2,592
BTMPV	17,636	19,297	21,706	23,741	23,795	26,023
CC	16,421	16,135	16,421	16,135	16,421	16,135
Coal	0	0	0	0	0	0
Cogen	1,892	1,935	1,892	1,935	1,514	1,574
CT	8,066	7,833	8,066	7,833	8,066	7,833
DR	2,636	2,635	2,636	2,611	2,636	2,611
Geothermal	1,771	1,768	2,747	2,736	2,747	2,736
Hydro	10,883	6,353	10,883	6,353	10,883	6,353
ICE	255	255	255	255	255	255
Nuclear	635	635	635	635	635	635
PSH	2,095	2,099	2,899	3,099	2,899	3,099
Solar	27,417	27,442	30,758	30,709	33,922	33,870
Steam	0	0	0	0	0	0
Wind	10,622	10,828	12,197	12,403	13,709	13,915
Other	0	0	0	0	0	0

- RESOLVE BTMPV installed capacity total is at customer side whereas SERVM BTMPV installed capacity is grossed up for T&D losses
- RESOLVE Hydro installed capacity is based on nameplate whereas SERVM Hydro installed capacity is based on peak annual production
- For all other unit categories, RESOLVE and SERVM installed capacity are comparable

Reliability results

Study Year	2026	2030	2032
LOLE (expected events/year)	0.0023	0.0005	0.0006
LOLH (expected hours of events/year)	0.0037	0.0005	0.0009
EUE (MWh)	2.09	0.03	0.65
annual load (GWh)	255,308	265,045	272,540
normalized EUE (%)	0.0000008%	0.0000000%	0.0000002%

- CAISO area loss-of-load-expectation (LOLE) is below the 0.1 target in all studied years – the portfolio is reliable
- The original 38 MMT Core Portfolio LOLE results described in the August 17th ruling were just under 0.1 LOLE. The very small LOLE results here are primarily due to the storage price variable change described above. When the price was too low, storage frequently did not have sufficient charge to meet peak demand hours. When the price was set to an appropriately high value, storage rarely deviated from SERVM's optimal schedule to meet hourly peak demand. The net effect is significant reduction in LOLE.
- As mentioned above, in 2022, staff expects to consider model changes to better account for climate change effects – which will likely increase LOLE (reduce reliability) relative to the results shown here

Generation results comparing RESOLVE and SERVM

Study Year	2026		2030		2032	
Model	RESOLVE	SERVM	RESOLVE	SERVM	RESOLVE	SERVM
Category	CAISO Energy Balance (GWh)		CAISO Energy Balance (GWh)		CAISO Energy Balance (GWh)	
CHP	8,967	10,089	8,967	9,888	7,173	7,947
Nuclear	5,108	5,563	5,108	5,136	5,108	5,563
Hydro In-state	22,964	25,228	22,962	25,324	22,962	25,398
Hydro From NW	11,331	11,000	11,293	11,000	11,109	11,000
CCGT	46,261	50,032	32,110	44,900	30,912	45,163
Peaker	1	6,005	1	5,572	1	6,936
Reciprocating Engine	10	142	13	136	12	159
Coal	0	0	0	0	0	0
Steam	0	0	0	0	0	0
BTM PV	33,477	33,039	41,202	40,618	45,168	44,529
Solar	71,328	71,381	80,846	80,740	89,735	89,888
Wind	27,908	26,951	34,197	32,989	40,793	37,200
Geothermal	10,082	14,112	17,411	21,093	17,411	20,617
Biomass	4,957	6,775	5,148	6,626	5,148	6,289
Pumped Storage Roundtrip Losses	-710	-1,770	-1,521	-2,223	-1,631	-2,313
Battery Storage Roundtrip Losses	-3,419	-2,686	-4,034	-2,967	-4,641	-2,975
Curtailment	-2,206	-3,392	-4,859	-5,331	-7,311	-10,262
Imports (unspecified)	24,011	10,636	24,668	7,173	23,536	5,671
Exports	-3,978	-7,389	-7,068	-10,958	-8,903	-13,506
Load	255,344	255,308	265,132	265,045	274,920	272,540
Sum of Supply	256,092	255,716	266,443	269,717	276,583	277,303

Observations on generation results

- RESOLVE and SERVM both use fuel and GHG price to determine dispatch order, however, RESOLVE's GHG price additionally includes RESOLVE's GHG shadow price, an amount consistent with the investment costs necessary to reduce emissions to RESOLVE's GHG target level
- This difference can result in the models selecting different dispatch orders and consequently different annual generation totals for in-state CCGTs vs. Peakers vs. Unspecified Imports, as seen in the table above. This effect was also observed in previous RESOLVE/SERVM comparisons.
- The totals for zero-emitting (including assumed NW hydro imports) and emitting generation (including unspecified imports) in both models remain comparable and any difference directly drives the emissions difference between the models
- As modeled in SERVM, CAISO is a net importer on an annual basis in 2026 but switches to being a net exporter in 2030 and 2032

GHG emissions results comparing RESOLVE and SERVM

Study Year	2026		2030		2032	
Model	RESOLVE	SERVM	RESOLVE	SERVM	RESOLVE	SERVM
Category	CAISO GHG Emissions (MMtCO2/Yr)		CAISO GHG Emissions (MMtCO2/Yr)		CAISO GHG Emissions (MMtCO2/Yr)	
CAISO Generator Emissions	21.2	27.1	15.9	24.8	14.8	24.8
Unspecified Import Emissions	10.3	4.6	10.6	3.1	10.1	2.4
CAISO BTM CHP Emissions	4.8	4.8	4.7	4.7	3.7	3.7
Total CAISO Emissions	36.3	36.5	31.1	32.5	28.6	31.0
SERVM - RESOLVE difference		0.2		1.4		2.4
	CAISO Generation and Imports (GWh)		CAISO Generation and Imports (GWh)		CAISO Generation and Imports (GWh)	
Zero-GHG	176,841	178,811	200,685	202,048	214,949	211,428
GHG-emitting	79,251	76,905	65,758	67,669	61,633	65,875

- **Zero-GHG generation**: Nuclear, Hydro from in-state and NW imports, Renewables net of storage losses, exports, and curtailment
- **GHG-emitting generation**: CHP, CAISO gas, Unspecified Imports

Observations on GHG emissions results

- CAISO-area GHG emissions modeled in SERVM are sufficiently close to those modeled in RESOLVE for all study years
- 2032 GHG emissions modeled in SERVM are 2.4 MMT CO2e more than modeled in RESOLVE. This is within the range of difference observed in all previous SERVM results that were compared to its equivalent RESOLVE result. Three model differences that contribute to GHG emissions differences are:
  - SERVM's 20 historical year average wind capacity factor is lower than RESOLVE's 3 historical year average, so wind generation in SERVM is less than in RESOLVE for the same installed capacity
  - SERVM imposed a storage discharge cap that tends to limit the amount of solar generation that can be stored for use during the evening peak. With the cap in place, curtailment, imports, and exports increased while storage round trip losses decreased. In-state gas generation stayed about the same. The net effect is increased emissions from higher imports.
  - The effect of the two models selecting different dispatch orders, described in generation results above, can also contribute to GHG emissions differences

Criteria pollutant analysis of the updated 38 MMT Core Portfolio proposed for the PSP

Background – criteria pollutants analysis

- Statute directs the Commission's IRP process to ensure that LSEs "minimize localized air pollutants and other greenhouse gas emissions, with early priority on disadvantaged communities "(PU Code 454.52 (a)(1)(H))
- Commission staff last presented a comprehensive criteria pollutants analysis in the presentation Updated Criteria Pollutant Analysis, 2/21/2020, found under the heading "Reference System Plan Decision and Materials" on the 2019-2020 IRP Events and Materials page. This presentation included details on:
  - Analysis steps using SERVM outputs
  - Methods to estimate start NOx emissions and normal operation NOx emissions
  - Data sources for estimating emission factors
  - Methods to summarize results by resource type, CARB air basin, year, and Disadvantaged Community (DAC) status
- The following slides repeat this analysis for each study year with the 38 MMT Core Portfolio updated with the 2020 IEPR mid, High EV demand forecast. Refer to the 2/21/2020 presentation for details on methods and data sources.

2026 California-wide capacity, energy, fuel burn, and criteria pollutants (metric tons) by unit category

Unit Category	Capacity, MW	Annual generation, TWh	Fuel Burn, millions of MMBtu	NOx, MT	PM 2.5, MT	SO2, MT
Biomass	615.0	4.6	55.4	4,850.6	1,801.7	693.0
CC	20,713.7	59.0	434.4	1,503.6	1,298.9	122.3
Cogen	1,960.7	10.1	76.9	1,103.2	228.8	24.3
Biogas	289.7	2.1	27.9	1,329.3	358.7	449.4
CT	10,449.7	7.9	81.6	462.7	242.3	23.0
Geothermal	2,147.7	16.7	68.8	160.2	169.7	0.0
Steam	446.0	0.1	0.9	5.0	3.2	0.3
ICE	304.5	0.2	1.5	15.2	6.9	0.5
Solar_Thermal	997.0	3.4	3.4	2.4	0.0	0.0
Total	37,924.0	104.0	750.8	9,432.1	4,110.2	1,312.8

- Biomass followed by biogas units have high emission intensities, emitting a large share of total criteria pollutants despite producing relatively small amounts of energy
- CC units have low emission intensity but still emit a significant share of total criteria pollutants since they produce large amounts of energy

2026 California-wide generation and NOx (metric tons) for CCs and CTs by start and normal operating states

Generation

	In Start (TWh)	Normal Operations (TWh)	Total (TWh)	% in startup
CC	1.1	58.0	59.0	1.8%
CT	0.8	7.1	7.9	9.9%
Total	1.8	65.1	66.9	2.7%

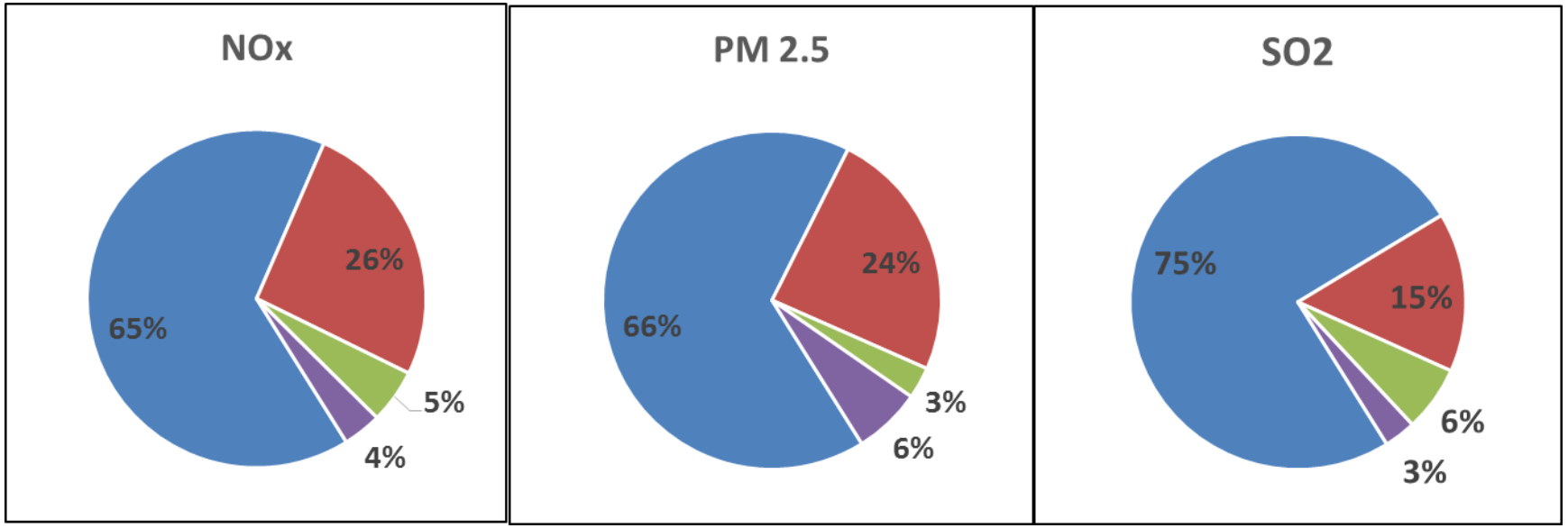
NOx emissions

	In Start (MT)	Normal Operations (MT)	Total (MT)	% in startup
CC	221.9	1281.7	1,504	14.8%
CT	97.5	365.2	463	21.1%
Total	319	1,647	1,966	16.2%

- Startup generation represents 2.7% of the total generation for CCs and CTs, but 16.2% of the total NOx emissions for these resource categories
- Total 2026 NOx emissions from CCs and CTs is 1,966 MT per year. According to CARB's estimated Statewide Emissions page, the average daily NOx emissions for 2017 is 1,620 Tons per day, or 1,470 MT per day.
  - This infers that CCs and CTs are estimated to emit annually in 2026 a similar magnitude of NOx to recent average daily NOx emissions from all sources, implying CC and CT emissions are a small fraction of total emissions.

2026 California-wide electric sector criteria pollutants (metric tons) by Disadvantaged Community (DAC) status

Category	NOx, MT	PM 2.5, MT	SO2, MT
In DAC	2,430	995	202
Not in DAC	6,169	2,725	987
Unknown	487	125	83
Out of State	347	265	40
Total	9,432	4,110	1,313



- DACs contain about 25% of California's population
- **In DAC**: Emissions from generating units located in disadvantaged communities as defined by the California Environmental Protection Agency and in D.18-02-018 (even if the emissions may migrate beyond)
- **Not in DAC**: Emissions from generating units not located in disadvantaged communities (even if emissions may migrate into such communities)
- **Unknown**: Staff was unable to map some of the smaller resources
- **Out of State**: Specified imports of emitting generation, such as the natural gas-fired Intermountain Combined Cycle in Utah, and the La Rosita and Termoelectrica de Mexicali power plants in Mexico. Emissions from unspecified imports are not considered.

2026 California-wide electric sector criteria pollutants (metric tons) by CARB air basin

Region Type	Region Name	Number of emitting generators in region	NOx, MT	PM 2.5, MT	SO2, MT
Basin	South Coast	105	1786.1	694.7	333.4
	San Joaquin Valley	65	1232.4	659.8	132.5
	Sacramento Valley	44	2234.6	894.0	318.7
	San Francisco Bay Area	43	761.0	320.5	112.9
	Salton Sea	32	240.8	116.4	25.7
	San Diego	26	283.2	146.2	27.9
	North Coast	12	887.6	266.1	92.3
	Lake County	8	19.3	53.1	0.0
	Mojave Desert	8	202.9	165.9	15.1
	South Central Coast	7	83.3	55.7	24.8
	North Central Coast	6	193.8	97.8	19.7
Non-Basin	Out of State	9	347.0	265.0	40.2
	Unknown	76	486.9	125.5	82.7
Other	Multiple	8	673.1	249.4	86.9
All	**Total**	**449**	**9432.0**	**4110.1**	**1312.8**

Multiple: includes the Mountain Counties, Great Basin Valleys, and Northeast Plateau basins. Because these basins all contained less than 5 individual generators each, staff aggregated their results into one category to preserve confidentiality of individual generator data.

2030 California-wide capacity, energy, fuel burn, and criteria pollutants (metric tons) by unit category

Unit Category	Capacity, MW	Annual generation, TWh	Fuel Burn, millions of MMBTU	NOx, MT	PM 2.5, MT	SO2, MT
Biomass	615.0	4.4	53.4	4,667.1	1,735.9	667.7
CC	20,482.7	54.4	400.0	1,437.1	1,196.0	112.7
Cogen	1,932.9	9.9	75.3	1,075.7	224.2	23.8
Biogas	289.7	2.0	26.4	1,261.1	337.8	424.8
CT	10,449.7	7.6	78.0	454.3	231.5	22.0
Geothermal	3,006.4	23.2	95.5	161.1	170.6	0.0
Steam	272.0	0.1	1.1	5.2	3.7	0.4
ICE	304.5	0.2	1.6	15.7	7.1	0.5
Solar_Thermal	997.0	3.4	3.4	2.4	0.0	0.0
Total	38,349.9	105.1	734.7	9,079.8	3,906.9	1,251.9

- Biomass followed by biogas units have high emission intensities, emitting a large share of total criteria pollutants despite producing relatively small amounts of energy
- CC units have low emission intensity but still emit a significant share of total criteria pollutants since they produce large amounts of energy

2030 California-wide generation and NOx (metric tons) for CCs and CTs by start and normal operating states

Generation

	In Start (TWh)	Normal Operations (TWh)	Total (TWh)	% in startup
CC	2.6	51.7	54.4	4.8%
CT	0.8	6.8	7.6	10.4%
Total	3.4	58.5	62.0	5.5%*

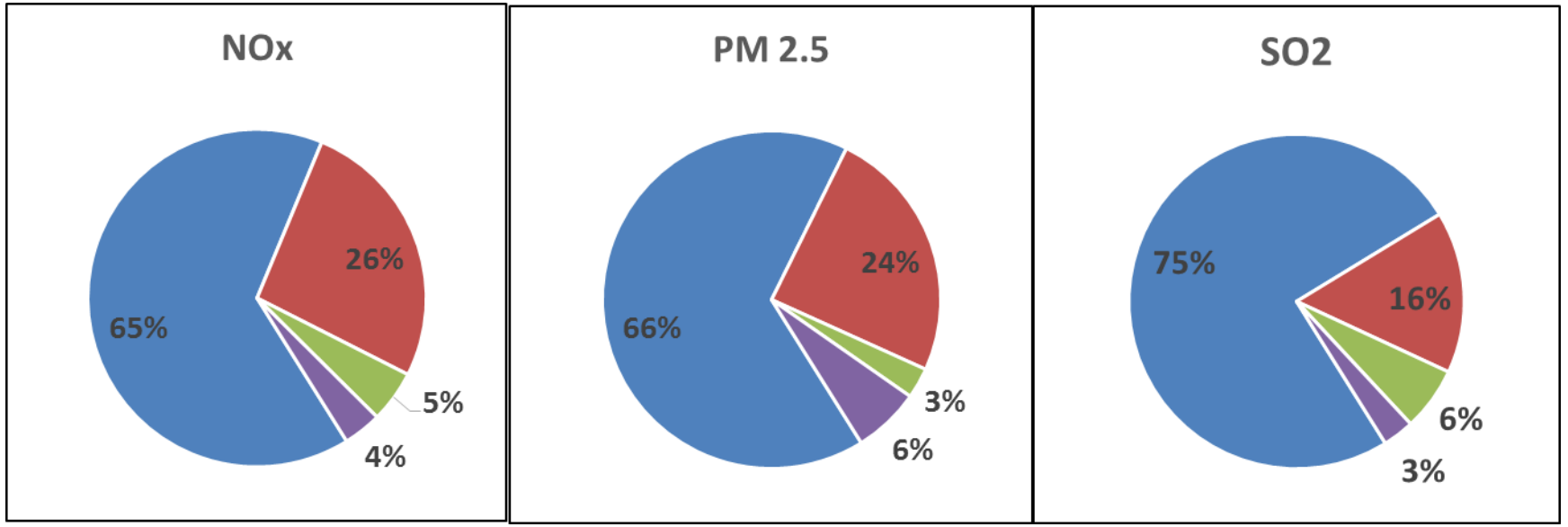
NOx emissions

	In Start (MT)	Normal Operations (MT)	Total (MT)	% in startup
CC	246.2	1,190.9	1,437	17.1%
CT	93.9	360.4	454	20.7%
Total	340	1,551	1,891	18.0%*

- Startup generation represents 5.5% of the total generation for CCs and CTs, but 18.0% of the total NOx emissions for these resource categories
- Total 2030 NOx emissions from CCs and CTs is 1,891 MT. According to CARB's estimated Statewide Emissions page, the average daily NOx emissions for 2017 is 1,620 Tons per day, or 1,470 MT per day.
  - This infers that CCs and CTs are estimated to emit annually in 2030 a similar magnitude of NOx to recent average daily NOx emissions from all sources, implying CC and CT emissions are a small fraction of total emissions.

2030 California-wide electric sector criteria pollutants (metric tons) by Disadvantaged Community (DAC) status

Category	NOx, MT	PM 2.5, MT	SO2, MT
In DAC	2,382	956	196
Not in DAC	5,915	2,586	941
Unknown	451	115	77
Out of State	332	250	38
Total	9,080	3,907	1,252



- DACs contain about 25% of California's population
- **In DAC**: Emissions from generating units located in disadvantaged communities as defined by the California Environmental Protection Agency and in D.18-02-018 (even if the emissions may migrate beyond)
- **Not in DAC**: Emissions from generating units not located in disadvantaged communities (even if emissions may migrate into such communities)
- **Unknown**: Staff was unable to map some of the smaller resources
- **Out of State**: Specified imports of emitting generation, such as the natural gas-fired Intermountain Combined Cycle in Utah, and the La Rosita and Termoelectrica de Mexicali power plants in Mexico. Emissions from unspecified imports are not considered.

2030 California-wide electric sector criteria pollutants (metric tons) by CARB air basin

Region Type	Region Name	Number of emitting generators in region	NOx, MT	PM 2.5, MT	SO2, MT
Basin	South Coast	103	1770	668.3	324.6
	San Joaquin Valley	65	1171.7	617.4	124
	Sacramento Valley	44	2112.4	846.8	300.8
	San Francisco Bay Area	43	736.1	300.7	106.8
	Salton Sea	32	295.5	136.4	30.4
	San Diego	26	269.2	136.4	26.1
	North Coast	12	831.3	250.4	86.4
	Lake County	8	19.10	52.6	0
	Mojave Desert	8	187.4	152.1	13.8
	North Central Coast	6	185.4	89	18.3
	South Central Coast	6	79.9	52.6	23.2
Non-Basin	Out of State	9	332.2	250.4	38.0
	Unknown	80	450.7	115.5	76.7
Other	Multiple	8	638.8	238.3	82.8
All	**Total**	**450**	**9079.7**	**3906.9**	**1251.9**

Multiple: includes the Mountain Counties, Great Basin Valleys, and Northeast Plateau basins. Because these basins all contained less than 5 individual generators each, staff aggregated their results into one category to preserve confidentiality of individual generator data.

2032 California-wide capacity, energy, fuel burn, and criteria pollutants (metric tons) by unit category

Unit Category	Capacity, MW	Annual generation, TWh	Fuel Burn, millions of MMBtu	NOx, MT	PM 2.5, MT	SO2, MT
Biomass	613.5	4.2	50.9	4,440.9	1,653.6	636.0
CC	20,417.1	55.0	404.8	1,460.8	1,210.5	114.0
Cogen	1,573.1	7.9	60.6	967.3	180.1	19.1
Biogas	289.7	1.9	24.9	1,195.1	318.6	402.1
CT	10,449.7	9.3	94.5	552.1	279.8	26.5
Geothermal	3,006.4	22.8	93.8	158.9	168.3	0.0
Steam	272.0	0.1	1.2	6.7	4.2	0.4
ICE	304.5	0.2	1.8	17.8	8.1	0.6
Solar Thermal	997.0	3.4	3.4	2.4	0.0	0.0
Total	37,923.0	104.7	735.9	8,802.1	3,823.2	1,198.7

- Biomass followed by biogas units have high emission intensities, emitting a large share of total criteria pollutants despite producing relatively small amounts of energy
- CC units have low emission intensity but still emit a significant share of total criteria pollutants since they produce large amounts of energy

2032 California-wide generation and NOx (metric tons) for CCs and CTs by start and normal operating states

Generation

	In Start (TWh)	Normal Operations (TWh)	Total (TWh)	% in startup
CC	1.2	53.7	55.0	2.3%
CT	0.9	8.4	9.3	9.7%
Total	2.2	62.1	64.3	3.3%

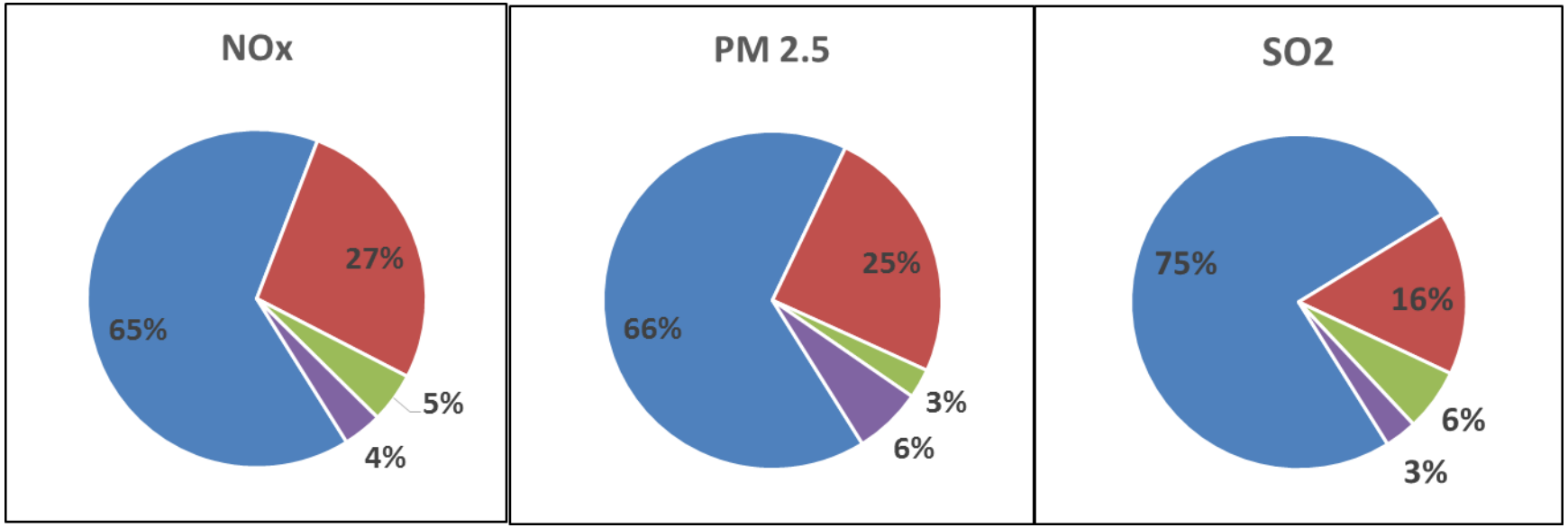
NOx emissions

	In Start (MT)	Normal Operations (MT)	Total (MT)	% in startup
CC	262.1	1198.7	1,461	17.9%
CT	117.3	434.8	552	21.2%
Total	379	1,634	2,013	18.8%

- Startup generation represents 3.3% of the total generation for CCs and CTs, but 18.8% of the total NOx emissions for these resource categories
- Total 2032 NOx emissions from CCs and CTs is 2,013 MT. According to CARB's estimated Statewide Emissions page, the average daily NOx emissions for 2017 is 1,620 Tons per day, or 1,470 MT per day,
  - This infers that CCs and CTs are estimated to emit annually in 2032 a similar magnitude of NOx to recent average daily NOx emissions from all sources, implying CC and CT emissions are a small fraction of total emissions.

2032 California-wide electric sector criteria pollutants (metric tons) by Disadvantaged Community (DAC) status

Category	NOx, MT	PM 2.5, MT	SO2, MT
In DAC	2,357	945	189
Not in DAC	5,697	2,522	900
Unknown	421	108	72
Out of State	327	248	37
Total	8,802	3,823	1,199



- DACs contain about 25% of California's population
- **In DAC**: Emissions from generating units located in disadvantaged communities as defined by the California Environmental Protection Agency and in D.18-02-018 (even if the emissions may migrate beyond)
- **Not in DAC**: Emissions from generating units not located in disadvantaged communities (even if emissions may migrate into such communities)
- **Unknown**: Staff was unable to map some of the smaller resources
- **Out of State**: Specified imports of emitting generation, such as the natural gas-fired Intermountain Combined Cycle in Utah, and the La Rosita and Termoelectrica de Mexicali power plants in Mexico. Emissions from unspecified imports are not considered.

2032 California-wide electric sector criteria pollutants (metric tons) by CARB air basin

Region Type	Region Name	Number of emitting generators in region	NOx, MT	PM 2.5, MT	SO2, MT
Basin	South Coast	101	1738.8	670.0	312.6
	San Joaquin Valley	62	1114.6	584.8	116.8
	Sacramento Valley	43	2020.0	815.9	286.6
	San Francisco Bay Area	42	748.3	315.3	103.9
	Salton Sea	32	290.7	134.7	29.9
	San Diego	26	274.6	141.0	25.6
	North Coast	12	785.4	237.9	81.5
	Lake County	8	18.8	51.8	0.0
	Mojave Desert	8	179.8	145.3	13.2
	North Central Coast	6	190.9	90.4	17.9
	South Central Coast	6	78.7	50.6	21.9
Non-Basin	Out of State	9	327.5	248.1	37.1
	Unknown	70	421.2	108.1	72.1
Other	Multiple	8	612.7	229.2	79.4
All	**Total**	**433**	**8802.0**	**3823.1**	**1198.5**

Multiple: includes the Mountain Counties, Great Basin Valleys, and Northeast Plateau basins. Because these basins all contained less than 5 individual generators each, staff aggregated their results into one category to preserve confidentiality of individual generator data.

Recap summary of results

For the 38 MMT Core Portfolio updated to pair with the 2020 IEPR managed mid demand forecast and high electric vehicle demand:

- LOLE is below the 0.1target in all studied years – the portfolio is reliable
- Installed capacity is generally aligned with the same modeled case in RESOLVE
- Annual generation results are reasonable and differences from RESOLVE can be explained by certain differences between the two models
- Annual emissions are sufficiently close to the 38 MMT statewide target in 2030, and to what is modeled in RESOLVE in 2026 and 2032
- Total criteria pollutants from California electric generators decrease about 7% between 2026 and 2032 due to a shift from fossil generation to geothermal and other renewable generation
- Findings on electric sector criteria pollutants are consistent with those in the previous staff analysis (2/21/2020)